Knowledge Sharing in Research Buildings and about their Design

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Abstract
Knowledge sharing is essential in present day society which is focused on innovation. Research driven organisations put a lot of effort in stimulating the knowledge exchange between their employees and are increasingly asking their Corporate Real Estate (CRE) managers to become involved in this process. They need to provide accommodation designed for people to meet and share knowledge, and look for architects to help them achieve this difficult goal. This paper will help them in two ways: 1) by showing in which way design can stimulate knowledge sharing in a research building, and 2) by making a contribution to the knowledge sharing between the parties involved in designing the workplaces of these research buildings.

CRE managers and designers use a certain terminology to describe (their demands for) a design. They use several layout terms that are also used by CRE academics in their studies. These layout descriptions, however, do not provide quantitative information on how the design actually stimulates knowledge sharing and cannot be implemented straight into a design by the architect either, which can cause confusion and miscommunication. Space syntax variables do show quantifiable outcomes and are unambiguous in their interpretation, but are part of a language that CRE managers do not use. Therefore, this paper first describes a literature study on mentioned design terms to stimulate knowledge sharing between employees and connects these terms with possible space syntax variables to measure them. The results are tested in an exploratory case-study with 138 employees of a large research driven organisation in the Netherlands.

Both co-presence and movement can stimulate knowledge sharing, and can be quantified with proximity, accessibility and other configuration measures. Results of the case study on co-presence show that VGA connectivity (the number of visible workplaces) is the strongest predictor of the number of knowledge sharing interactions a person has at work. The information from these types of studies can be used to build a tool that helps CRE managers become involved in the strategic decision making process of their organisation and prove the added value of their work.

Introduction

Corporate Real Estate decisions used to be made on a property-by-property basis with no overall strategy. Also, the real estate choices were often made without consultation and coordination with other important business units, such as human resources, technology, capital and communication (Gibler, Black and Moon, 2002). Lately, real estate is getting more and more attention from general management, and has formed its own discipline named Corporate Real Estate Management (CREM). CREM can be described as: *"The management of a corporation's real estate portfolio by aligning the portfolio and services to the needs of the core business(processes), in order to obtain maximum added value for the businesses and to contribute optimally to the overall performance of the corporation."* (Dewulf, Krumm and de Jonge, 2000)

Although the main goal of general management for CRE might always be to limit the high costs of this resource (2nd after cost of labor), the focus appears to be moving towards a cost/benefit ratio. And 'benefit' in this ratio should be seen as a broader term, than just direct or indirect return on investment in real estate. Lindholm and Leväinen (2006) identified 5 additional ways in which CREM can add value to the organization. Besides direct return ('Reducing costs') and indirect return (increase in the 'Value of assets'), these are 'Promoting marketing and sales', 'Increasing innovation', 'Increasing employee satisfaction', 'Increasing productivity' and 'Increasing flexibility'.

Especially increasing innovation and knowledge sharing is a goal of organizations these days. Literature studies (Heerwagen et al., 2004; Brager et al., 2000) discuss that CREM might be able to add value to this by providing the right floor and building layout. Architects also claim to design new research buildings in such a way that they specifically stimulate knowledge sharing through open areas, special meeting places, etc. The problem for a CRE manager is how to prove to general management that a new (or improved) building will indeed stimulate knowledge sharing, and thus is worth the investment. Discussions between CREM and general management and also between CREM and architects can go on forever, if there is no actual proof of the added value of a suitable layout for knowledge sharing. So far this proof has not been given, and an important reason is the lacking of suitable CRE measures. As Franz and Wiener (2005) state, previous studies "*relied on qualitative descriptions of selected features of space, which makes them difficult to compare.*" Also Hillier (1996) and Franz, Heyde and Bülthoff, von der (2005) point out that controlling the architectural variable is the key methodological difficulty in studies of architectural determinism. So finding suitable measures is the first step necessary to help CREM prove the importance of a building for knowledge sharing, and the goal of this paper.

The first section gives an overview of what knowledge sharing is, by giving definitions and going into the process of knowledge sharing between employees. The next section describes a literature study on the relationship between building aspects and knowledge sharing, and shows the shortcomings of the measures used by CREM up till now. Then a case study will be described, in which the most relevant measures of spatial network analyses are tested, followed by a discussion on their suitability to tackle the mentioned problems.

Knowledge sharing

Knowledge sharing can only take place between people through some form of communication (Te'eni, 2006). Although communication in itself is a complicated issue, it is often portrayed by academics with a simple linear model developed by Shannon (Shannon and Weaver, 1949). To set up a similar model for knowledge sharing would lead to a more complicated picture (see figure 1). Shannon's model would have to be extended with the distinction between data, information and knowledge (Meadow and Yuan, 1997); a hierarchy which still causes a lot of discussion among knowledge management academics. Also, the linearity will disappear. Otter (2005) describes a first circular relationship: *"the judging of data, its possible acceptance as information, and its incorporation into a knowledge base all depend on use of the existing knowledge base."* This implies a continuous loop in the model in the mind of the receiver. A second loop would be based on academics looking at knowledge as a dynamic concept (Spiegler, 2003; Nonaka and Takeuchi, 1995; Van Daal, De Haas en Weggeman, 1998), namely as *"the capacity for effective action"* (Spiegler, 2003). The actions one can undertake with knowledge will lead to the creation of new data. Weggeman (1997) best portrays this circularity in a knowledge sharing model.

The definition of knowledge by Davenport and Prusak (Aarons, 2006) represents this way of thinking: *"Knowledge is a fluid mix of framed experience (E), values (A), contextual information (I), and expert insight (S) that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the mind of knowers."* These knowers are both the transmitter and the receiver. This definition encompasses implicitly the common distinction in most knowledge management literature between explicit knowledge (information) and tacit knowledge (experiences, skills, attitude) in accordance with Polanyi (1966).

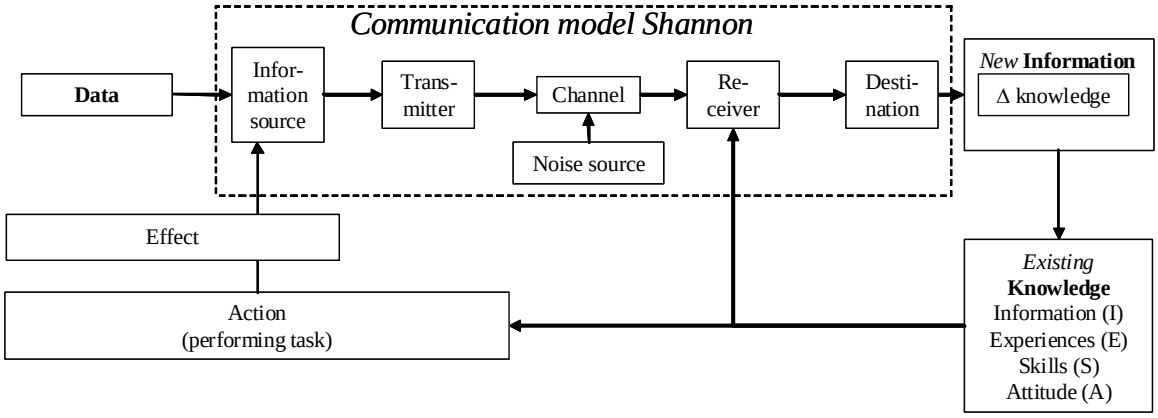

Figure 1

Knowledge sharing model (Adapted from Weggeman, 1997)

Activities that lead to knowledge sharing have been identified through observation of researchers in their work environment by Berends (2003). He identified a taxonomy of 29 'moves'; a move being an interaction during which knowledge is shared in a certain way. They are grouped into 5 categories which seem very suitable to use as measures for knowledge sharing in an organization (see table 1). They are very commonly used words for activities and therefore it should be clear to both researchers and the subjects that will be studied, what is meant by them. The single moves were used as examples of what an activities category encompasses. While certain interactions have been shown to help in sharing explicit knowledge, it is said that they are not always enough to share tacit knowledge. Giving 'descriptions' is such an interaction; reporting on explicit information in either an oral or written form. For tacit knowledge sharing collaboration is better suited (Kahn, 1996), identified with interactions involving 'proposals', 'evaluations', 'questions' and 'actions'.

Explicit knowledge	**Descriptions** • reporting about others • describing something (own activities, own knowledge, own problem, findings or theory, earlier interaction, experiment, own results, technology) • giving/asking someone a document, cd or other medium containing information
Tacit knowledge	**Actions** • showing/demonstrating • on the spot calculating or trying • expressing observation during experiment
	Questions • asking a question • questioning • asking for help
	Proposals • hypothesizing • suggesting something (technical solution, experiment, new research) • warning • instructing • referring to (person, literature or other interaction)
	Evaluations • giving arguments • agreeing • rejecting • concluding • redescribing and summarizing

Table 1

Knowledge sharing activities during interactions (Adapted from Berends, 2003)

It is also interesting to check how much of the knowledge that is shared face-to-face is really tacit. Was it necessary to have an interaction with this person or do alternative sources exist to gather this knowledge. A clear explicit knowledge form is a non-human source, like the internet, a dvd or a book. And knowledge is also less tacit, if more people within an organization contain the same knowledge.

A last important measure is the intentionality of an interaction. For interactions that are scheduled in advance it is very likely that they have not been a result from the building design. Organizational structure and projects at hand are more likely to steer who schedules meetings with whom to discuss certain things. For an analysis of the impact of layout, it is best to remove these interactions from the database. The case study (discussed later in detail) confirmed this, showing that the scheduled interactions were of a different nature than the unscheduled ones: they take place more often in the morning (42% started before 10am), last longer (53% lasted more than a half hour), were most of the interactions with large groups and accounted for 80% of all interactions in meeting rooms.

Impact of CRE on knowledge sharing

Rashid et al. (2005) mention 2 spatial behaviors that are responsible for face-to-face interactions of people:

- Movement (# people moving along a path)
- Co-presence (# active and/or inactive people visible from a path)

So these 2 behaviors might lead to possible knowledge sharing, because they influence the necessary interaction. Below, the most likely CRE aspects to provide movement or co-presence are discussed.

A content analysis of literature from the 90's until 2006 shows that knowledge sharing is not mentioned specifically as the intended goal in most of the layout studies. Instead similar and broader terms like cooperation or interaction are used with a focus on office-type buildings, what makes them easier to compare and to generalize their results. The office measures that are mentioned by the different authors are interpreted and assigned to movement and/or co-presence (see table 2). For Co-presence, 3 different measures are mentioned often, namely 'visual/aural accessibility', 'proximity' and 'meeting areas'. For movement, 2 measures were found, being 'layout of the floor' and the 'location within the building'.

Research driven organizations often work both in offices and in laboratory settings, which can be intertwined within one building. These buildings do not have typical office layouts like the ones studied by the authors in table 2. Studies of these types of research buildings are very scarce in real estate literature. But two groups of academics from architectural schools did have a look at them. In the late 80's/begin 90's at the Bartlett school of architecture and planning several studies have been done. Research on a sample of 24 floors in 7 laboratory buildings on 5 sites in the UK in several sectors was published in several papers (Penn and Hillier, 1992; Hillier and Penn, 1991; Hillier et al., 1985). A study of 7 other UK organizations with 'bench scale' laboratories was done around the same time (Hillier et al., 1990). Three aspects come forward to stimulate interaction, namely proximity, visibility and layout. At the Georgia institute of technology, a study of 2 laboratory buildings was performed (Serrato and Wineman, 1999). This showed that half of the interactions occurred within private offices of which again half was in an office of group leaders, lab directors or other managers. Only 5-6 % of the talking took place in hallways. The spread of these offices through the layout is what determined where the interactions took place. Surprisingly, proximity was not a strong predictor of interaction here. It was movement and approachability during such (standing close to hallway, not sitting at desk), which determined whether researchers interacted or not.

		Grajewski, 1992	Becker et al., 1995	Moenaert and Caeldries, 1996	Kahn and McDonough III, 1997	Bulte and Moenaert, 1998	Covi et al., 1998	Nonaka and Konno, 1998	Penn et al, 1999	Brager et al., 2000	Hargadon and Sutton, 2000	Ward and Holtham, 2000	Becker et al., 2003	Kauttu, 2003	Heerwagen et al., 2004	Shpuza, 2006	Rashid et al., 2006
Co-presence	Visual/aural accessibility		x			x	x			x	x				x		x
	Proximity	x	x		x	x		x				x	x		x		x
	Meeting areas						x	x	x								x
Movement	Layout of the floor		x	x					x	x	x		x	x	x	x	x
	Location within the building	x	x										x			x	x

Table 2
Office measures effecting cooperation

A remarkable difference between most of the office-studies and the laboratory studies is the way co-presence and movement are measured. The space syntax measures of the latter have not been used by any of the academics/consultants in the field of CREM. The office studies that do use space syntax measures come from the same institutions where the laboratory studies were done. The focus in these studies lies more on improving the architect's work than on the management of the building. So the same words are used to describe the building, but CREM studies have looked at these concepts from a qualitative viewpoint only without using quantitative space syntax measures. *"Apparently, the CRE community has not yet picked up on the existence of these methodologies"* (Appel-Meulenbroek and Feijts, 2007), which is a pity. This paper will therefore try to show the relevance, by using space syntax methodology on the CREM issue of proving added value; in this case by trying to provide evidence that layout can improve the amount of knowledge sharing between researchers.

Nonaka and Konno (1998) emphasize that tacit knowledge can only be exchanged through joint activities, as spending time/living in the same environment. This implies that co-presence is the most important effect of a building on knowledge sharing. However, Allen (1977) already showed that the effect of co-presence has a certain limit (in his study this was 30 meters, but this distance has not been duplicated in later studies and is questionable). Movement might have the potential to spread knowledge wider throughout the building, but as it appears only the explicit type. Since this paper is only an exploration of the suitability of space syntax methodology for CREM, it will only study the measures of co-presence and its effect on knowledge sharing in more depth. The next section describes suitable Space Syntax measures to quantify the building's co-presence potential.

Co-presence in Space Syntax terms

According to Franz, Heyde & Bülthoff (2005) isovists allow to generically describe spatial properties. For visual/aural accessibility they seem a logical choice. Tandy appeared to be the originator of the term 'isovist' at a symposium landscapes in 1967 (Turner et al., 2001; Batty & Rana, 2004). Others state Benedikt (1979) as the first, because he introduced a set of analytic measurements of isovist properties to be used for analyzing spatial environments. An isovist as defined by Benedikt is *"the set of all points visible from a given vantage point in space and with respect to an environment"*. The viewpoint of the isovist will be the place where the researcher is working behind his computer. His vision can be obscured by walls, partitions, file cabinets, etc. An appealing side of isovists and visibility analysis is that they provide a description of space as how the user perceives it, interacts with it and moves through it (Turner et al., 2001; Turner, 2003) and

has the potential to reveal more of the life that occurs in a space than by just studying the space itself (Peatross, 2001).

The isovist area and isovist perimeter seem relevant here, because they define the potential number of people that could have their workplace within someone's visible and aural accessibility. Also isovist occlusivity (m^1 of the perimeter of the isovist that is not formed by a solid object and thus permeable) seems a suitable measure. Batty (2001) tried to measure how far one could see as a proxy for how much one could see, with the maximum, minimum and average radials within the isovist. Combined, they form a measure of isovist compactness (average distance/maximum distance). A more compact place seems to be closer to representing co-presence, because seeing someone work at the end of a long hallway, does not provide aural accessibility for example.

Just as isovists describe single observation points, visibility graphs describe the layout of the floor as a whole from the viewpoint of visibility (Franz, Heyde and Bülthoff, von der, 2005) which is a big advantage. Each node can be seen as a potential place for another person, which is relevant both for co-presence and movement. The first application of visibility graph analysis (VGA) to buildings is allotted to Braaksma and Cook, who applied it to an airport terminal (Turner, 2001). An interesting measure for visual accessibility is the visual # of workplaces, which is measured by the VGA-connectivity measure, if only the viewpoints of the researchers are used to form a grid and not the rest of the layout.

Metric distance, corridor width, visual field and 3D spatial relationship all are important for office design (Shpuza, 2006). Haq & Zimring (2003) point out several studies that have shown that people get a different mental representation of a building when they get to know it. Their so-called 'route map' with topological relationships is said to change into a 'survey map', that has more accurate Euclidian properties. They confirmed this with their own study in 3 hospitals. So as soon as someone wants to walk over to a colleague's workplace and 2 options exist to reach him/her, the shortest one (in metric distance or time) will most probably be the preferred (and thus used) one. Therefore, the metric mean depth will be used as a measure for proximity. It can be generated by using the VGA grid to move, but measuring the metric distance. This is a close approximation of the actual metric distance, because it measures distance from the centre of one grid square to the centre of another, but does move around obstacles in the drawing. This analysis is done with a VGA of the entire building layout and then using only the values for the nodes assigned to a workplace in the analysis of its effect on knowledge sharing.

Since meeting areas are meant for interaction, observation showed a non-surprising result that a lot of talking takes place in them (Penn, Desyllas and Vaughan, 1999). These are mostly planned meetings though (as discussed before), and not so much a result from the layout. Also, a study of 4 organizations by Rashid et al. (2006) showed that no more than 11% of the interactions took place in a meeting room anyway. The workplace is where most interactions take place. The case study (discussed next in detail) confirms this, because only 5,6% of the interactions took place in meeting rooms, of which 80% were planned interactions. So no measures will be tested with regard to meeting areas.

Results

The Space Syntax data are generated with Depthmap version 7.12 on a grid of 500 mm. The data on knowledge sharing were gathered within a 2-storey building on the research campus of a large research organization in the Netherlands (see figure 2). During one week (in October 2007) 138 R&D employees filled in a logbook about each knowledge sharing interaction and the location where it took place. They constitute 52% of the entire building population and are spread out over both floors of the building with their office workplace. The small lab areas without daylight are concentrated around the corridors, and a few large lab areas with less specific climate conditions are located in areas similar to the offices.

The logbooks on knowledge sharing provided information on all work related interactions between colleagues working in this particular building. Only the interactions between participants of the

case study are taken into account for the analyses, so the ones with non-participants were removed (=32%). After that 1145 entries in the logbooks remain for this particular week. The entries of all persons taking part in a certain interaction are matched to check if they give the same answers to the questions on knowledge sharing. This showed that only 59% of the interactions that took place, ended up in the logbooks of all interaction partners; a lot less than the participants thought to have filled in (ave. = 77,6%). A χ^2-analysis of the answers in the matches versus the non-matches did not show any relevant differences. Also, the answers of the matched partners were similar in 69-73% of the interactions. So the partners who forgot to log an interaction, are assigned duplicated entries with the information from the people who indicated sharing knowledge with them at that time. This led to a total of 918 matched interactions from 1907 entries, which are mostly between 2 persons (93%, vs. 6% between 3 pers. and 1% between 4 pers.). The results for knowledge sharing during these unscheduled interactions between participants are discussed below.

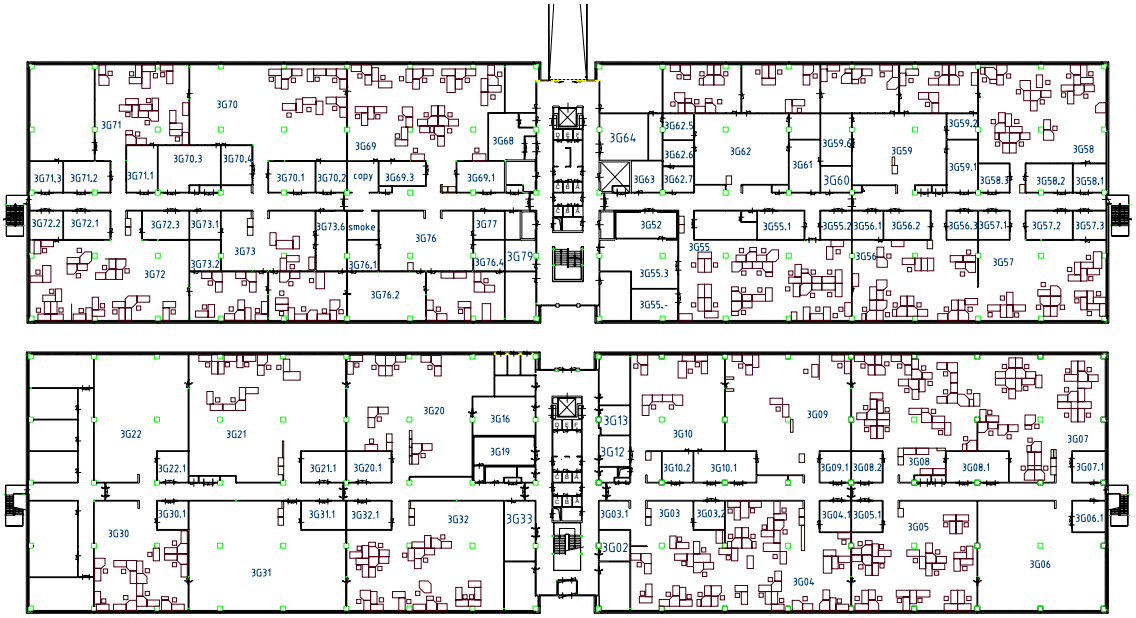

Figure 2
Layout case study building

First of all, 86,4% of the interactions took place between employees from the same department. This includes all one-on-one interactions. In another 10,3% of the interactions, only 1 person from another department was present. The influence of the department structure is obvious. Apparently, employees seldom share knowledge with people from another department. This confirms, that layout is not enough for people to meet, but can only give an extra boost, as stated before by others (Rashid et al., 2006).

During 56% of the interactions knowledge was shared by asking and answering questions, while the other 4 knowledge sharing activities only took place during 17-22% of the interactions (see table 3). In 73% of the interactions, only 1 type of activity took place, and 2 types of activities during another 20%. Because of this, there are no positive correlations between any activities that would have shown a preferred combination of them. The knowledge that was shared is very tacit, judging from the answers given to the question on a possible alternative source. Only 4,2% of the shared knowledge could also have been found in a book or other non-human source. And 77,2% was knowledge that only this particular person could provide. A χ^2-analysis of all the interactions with only 1 activity does not show any correlation between giving descriptions and a possible alternative source. So the data do not confirm that descriptions are only suitable to share explicit knowledge.

Most of the interactions took place at a workplace, with a total of 78,2%. The labs account for 14,4% of the interactions. Very few unscheduled interactions took place in the meeting areas, but

more surprisingly, the hallway or coffee machine also do not accommodate many unscheduled work related meetings. Perhaps, the coffee machine is more a place of informal talk about non-work related matters. Or maybe people forgot to log these interactions, although it does not seem likely that this would explain such a large difference with interactions at the workplace. Looking at the type of activities during the interactions, relatively more questions were asked in the hallway; short, but also longer interactions up to 15 minutes. In the meeting areas and at the coffee machine relatively fewer questions were asked and more evaluations took place, but these areas had very few interactions anyway. The lab areas see relatively more actions, which in 70% of the cases were completed within 15 minutes, which is not very long.

	Frequencies	Valid percent
KS activities	423	22,4%
Descriptions	321	17%
Actions	1067	56,4%
Questions	372	19,7%
Proposals	395	20,9%
Evaluations		
# of KS activities during the interaction		
1	1379	72,9%
2	376	19,9%
3	104	5,5%
4	25	1,3%
5	7	0,4%
Alternative source		
Yes, non human	40	4,2%
Yes, other person(s)	176	18,5%
No, only this person	733	77,2%
Location of interaction		
own workplace	802	42,2%
workplace of other	684	36,0%
meeting area	22	1,2%
lab	274	14,4%
coffee machine	81	4,3%
hallway	39	2,1%
Intentionality		
Intentional unscheduled visit	1358	71,8%
Initiated after coincidental visual contact	533	28,2%

Table 3
Values of knowledge sharing measures

In 28% of the interactions, people started sharing knowledge because they happened to bump into each other. These coincidental interactions take place significantly more often in the hallway and at the coffee machine than the intentional ones, but still these locations only account for 14% of the coincidental interactions. For 72% of the interactions, people decided to walk over to the other person, or have their workplaces so close that they can talk with each other from behind their desk.

To study the influence of co-presence, first a correlation analysis of all the space syntax variables was done. This shows that the isovist measures 'area', 'perimeter', 'occlusivity' and 'compactness' and the VGA 'connectivity' of the workplaces are not different measures for visual/aural accessibility. The correlation coefficients (see table 4) vary from -0,496 (compactness with connectivity) up to 0,975 (perimeter with occlusivity). 'Metric mean depth', the measure for proximity, only correlates with 'connectivity' and less strongly (-0,394). It is no surprise that all these variables correlate so much, because the design aspects that they measure are very related. It makes the analysis of layouts easier, because some of them can be discarded in the future. With a stepwise multiple regression the best predictor can be found, which turned out to be 'connectivity'. It explains 17% of the variability in the number of interactions (sign. = 0,000), and the rest is excluded from the equation because they have no additional explanative power.

	Isovist Area	Isovist Perimeter	Isovist Compactness	Isovist Occlusivity	Connectivity	Metric mean depth
Isovist Area	1	,933(**)	-,784(**)	,855(**)	,723(**)	-,106
Isovist Perimeter	,933(**)	1	-,879(**)	,975(**)	,627(**)	-,073
Isovist Compactness	-,784(**)	-,879(**)	1	-,855(**)	-,496(**)	,026
Isovist Occlusivity	,855(**)	,975(**)	-,855(**)	1	,563(**)	-,076
Connectivity	,723(**)	,627(**)	-,496(**)	,563(**)	1	-,394(**)
Metric mean depth	-,106	-,073	,026	-,076	-,394 (**)	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 4

Pearson correlations between space syntax measures

Further statistical analysis of the different knowledge sharing activities gives no significant results of any influence of co-presence. Apparently, more or less co-presence has no influence on the type of KS activities that a person carries out (relatively to the total number of activities of that person). So when a person is put within visibility of more people, his/her number of interactions increases in the same amount for all types of knowledge sharing activities.

Discussion and conclusions

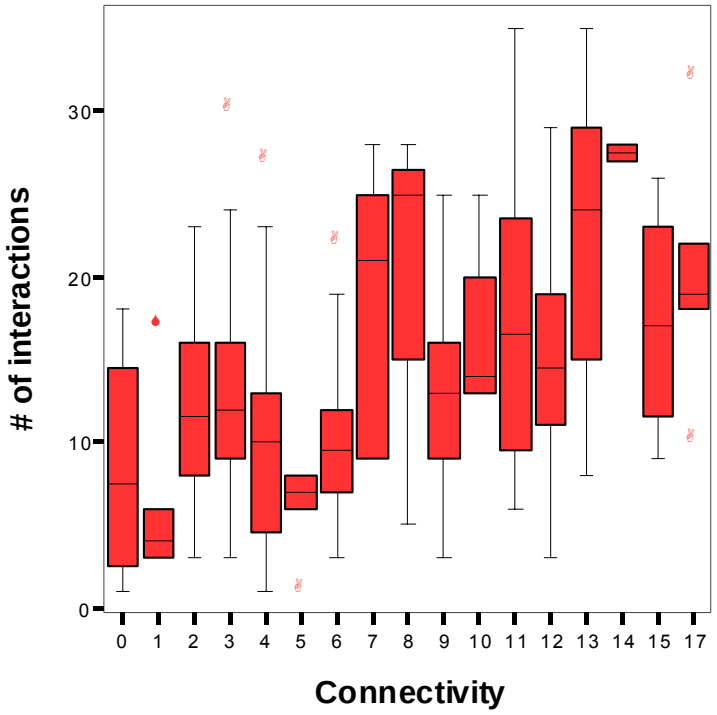

Figure 3

Box plot # of interactions – connectivity

With regard to co-presence and its influence on knowledge sharing, only connectivity came forward as a relevant measure. And when the data on connectivity are put in a box plot with the number of interactions (see figure 3), it becomes visible that an explanatory power of 17% is not that much. It was to be expected that the relationship between co-presence and knowledge sharing is not extremely strong, because there are many other aspects that influence knowledge sharing. Berends (2003) executed an extensive literature study and identified a long list, with aspects related to the attitude of both transmitters and receivers (e.g. trust, motivation), to the organizational context (e.g. culture, orientation and formalization) and several other factors. But

now a layout that provides a lot of co-presence can be added to that list. Many organizations are game for any increase in knowledge sharing that can be accomplished. It would be interesting to study the relative effect of the layout with regard to the rest of the list, although that seems an impossible task. It would create an even better foundation for the assessment whether to invest in real estate (the layout) or in other resources.

In this paper only knowledge sharing and co-presence were studied in depth. It was an exploratory analysis of just a few space syntax measures, but has already shown that it can be interesting for CRE managers to use more quantitative measures to describe a building layout. As Appel-Meulenbroek and Feijts (2007) pointed out, layout has the potential to add value in other ways too, like increasing organizational flexibility and productivity and employee satisfaction. Further research into those organizational goals could find more relevant quantitative measures of the layout. Also, a lot of other space syntax measures are related to movement, and still have to be tested for their influence on knowledge sharing. With the measures that turn out to be relevant, it is possible to create a powerful tool for CREM to prove the significance of an adequate layout for reaching organizational goals. Only the strongest predictors have to be used in such a tool, what keeps it clear and practical to use. Programs like Depthmap, can visualize the measures onto the building layout (see figure 4), which makes the information better accessible for general management and other non-real estate people.

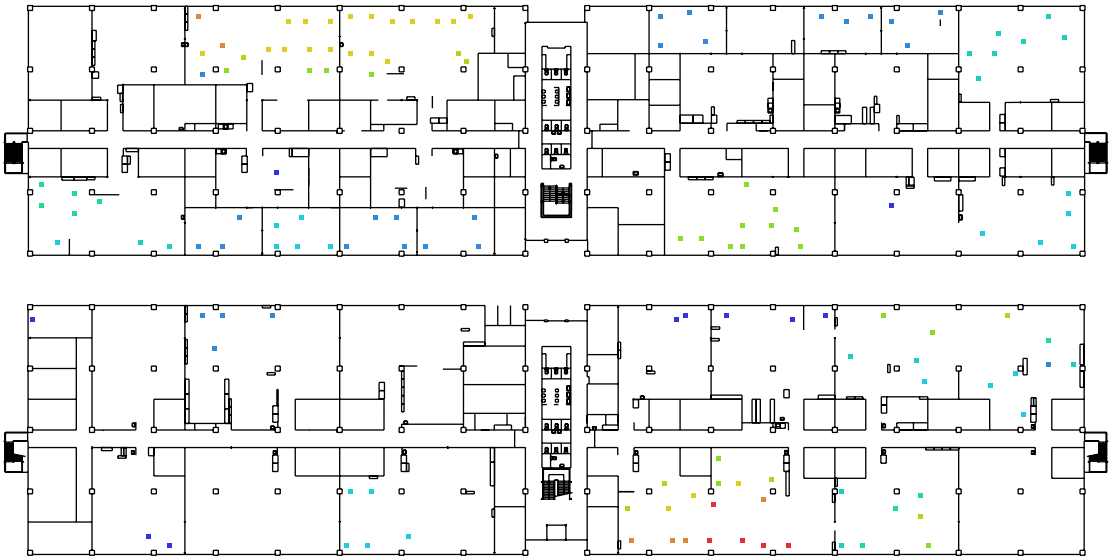

Figure 4
Connectivity of participants case study

A lot of knowledge about the layout and its effects can be gained this way. That makes it possible to discuss different layout options and the effects they would have on the organization, and thus choose the right real estate strategy. On a more operational level, it could also be practical to use the visualizations to talk about who should sit where. And in discussions with the architect possible changes and variations in the design, immediately can be assessed on their impact on the organization. To conclude, this paper has tried to shed a light on knowledge sharing in 2 ways. First, how knowledge sharing in a research building takes place, and second, how knowledge about the layout can be shared between the different parties involved in the design process of research buildings. Both are worth to be stimulated.

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